Entropy and Size in HIC

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Abstract

Distinct entropy definitions have been used to obtain an inverse correlation between the residual size and entropy for Heavy Ion Collisions. This explains the existence of several temperatures for different residual size bins, as reported elsewhere (Natowitz et. al., 2002). HIC collisions were simulated using binary interaction LATINO model where Pandharipande potential replicates internucleonic interaction. System temperature is defined as the temperature obtained when Kinetic Gas Theory is applied to the nucleons in the participant region. Fragments are detected with an Early Cluster Recognition Algorithm that optimizes the partitions in energy space.

1 Introduction

Recent studies of the caloric curve in Heavy Ion Collisions have reported a system finite size effect for caloric curve limit temperatures (Natowitz y otros, 1995), as well as problems related to the use double isotope thermometers for the sake of limit temperature estimation (Viola et. al., 1999). As a matter of fact, when different thermometers are used, distinct caloric curve shapes have been obtained such as rise-plateau-rise (Pochodzalla et. al., 1995), rise-plateau (Serfling et. al., 1998), or a rise-rise shape without the expected plateau linked to a first order phase transition (Hauger et. al., 1996). D′Agostino et. al. have developed a general protocol for the thermostatic analysis dealing with incomplete experimental data, showing that abnormal fluctuations in kinetic energy are genuine signature of a first order phase transitions in finite systems, delivering a limit temperature estimation close to 5.5 MeV for the collision of 200 particles against Au as target (D′Agostino et. al., 2002). Raduta et. al. have obtained a limit temperature in the range of 6 to 7 MeV, improving the computation of peaks of the microcanical caloric capacity, refining the primary breakup computation and including secondary particles emission (Raduta et. al., 2000). Borderie et. al. have applied microcanonical analysis of experimental data in the Fermi energy range,

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confirming the presence of a liquid-gas phase transition (Borderie et. al., 2004).

Beyond all these technical elements, remains the fundamental question of a unique caloric curve limit temperature, as sustained in (Pochodzalla et. al., 1997), for differente range of mass, charge and energy. Nevertheless, Natowitz et. al. have obtained an inverse correlation between limit temperature and residual size (Natowitz et. al., 2002), motivating several studies on the infuence of the residual size and its relation with other thermodynamical variables such as entropy.

As a matter of fact, Gross et. al. have shown that it is posible to define a phase transition in finite systems on the grounds of a Statistical Mechanics based on Boltzmann entropy definition (Gross et. al., 2001). Gibbs considered the microcanonical ensamble as the fundamental one and the canonical as an approximation, showing that the canonical ensamble fails in a phase transition (J.W. Gibbs, 1902). It is not essential to perform a thermodynamical limit (Lebowitz, 1999) neither are necessary extensivity (Lieb et. al., 1998), nor concavity or additivity (Lavanda et. al., 1990.). Other problem with finite systems is the equilibrium control and the extraction of thermostatic variables starting from observables, in order to detect a phase transition. In the case of HIC, the comparation of the observed channels with the statistical models (Bondorf et. al., 1995) suggests that a certain equilibrium has been reached (Desesquelles et. al., 1998.), though until now no phase transition has been identified beyond any doubt (D$'$Agostino et. al., 2000).

Any Boltzmann-Gibbs equilibrium is obtained when Shannon entropy information is maximized in a given Fock space considering restrictions in the mean values of the distinct observables. Chomaz et. al. have developed a general definition of a phase transition based on annomalies in the probability distribution of the observables, that can be applied to non-ergodic systems, namely ensambles which are not like Gibbs ensambles, or even to sets of events prepared in a dynamical way (Chomaz et. al., 2000). Raduta et. al. have obtained expresions for the temperate, heat capacity and entropy second derivative which are model independent though based in the microcanonical multifragmentation model, using them to analyze experimental results and obtaining evidence of a first order phase transition (Raduta et. al., 2001).

2 Methodology.

Heavy Ion Collisions were simulated using LATINO semiclassical model (Barrañón et. al., 1999) where a Pandharipande potential replicates binary interaction. Fragments are identified with an Early Cluster Recognition Algorithm that optimizes configurations in energy space. Ground states are produced generating random configurations in phase space and gradually reducing the partice speed. Particles are initially confined in a parabolic potential and systems is gradually frozen until the theoretical binding energy is attained. Microscopic Persistence is used to determine the time at which system gets frozen. Verlet Algorithm is used to numerically integrate the equations of motion, using time intervals that ensure

energy conservation in a 0.05evidence about phase transition and critical phenomena in finite and transient systems,name Heavy Ion Collisions (Barrañón et. al., 2003). Participant region temperature is computed applying Kinetic Gas Theory and excitation is obtained as the energy given to the residual. System entropy can be computed in terms of information entropy (Ma, 1999):

$$S = -\sum_{i=1}^{M} n_i ln(n_i) \tag{1}$$

or with the entropy of a classical gas (Huang, 1987):

$$S = log\Big[\big(\frac{1}{n}\big)\big(\frac{3T}{2}\big)\Big] + S_0 \tag{2}$$

Fragmentation time t_{ff} can be defined as the time where system breaks up in such a way that afterwards only some monomers are ejected. In orderto estimate t_{ff} it is necessary to measure the simmilarities of partitions at different times, which can be done using the Microscopic Persistence Coefficient (Strachan and Dorso, 1999), which is defined as the probability that two particles belonging to a fragment of partition X remain together in a fragment of partition Y:

$$P\big[X,Y\big] = \frac{1}{\sum_{fragmentos} n_i} \sum_{fragmentos} \frac{n_i a_i}{b_i} \tag{3}$$

where b_i is equal to the number of pairs of particles belonging to the cluster C_i of partition X while a_i is equal to the number of particle pairs belonging to cluster C_i of partition X that also belong to a given cluster C_i' of partition Y. n_i is the number of particles in cluster C_i. Therefore, fragment formation time can be defined as time where the Microscopic Persistence Coefficient is equal to one. At this moment, the biggest fragment is stable and multiplicity remains practically constant.

3 Results

As shown in Fig. 1, an inverse correlation is obtained between residual size and entropy, appying classical gas definition to the particles in the participant region (right). This is confirmed when an inverse correlation is obtained employing experimental data from (Natowitz et. al., 2002) (left), where limit temperature decreases with residual size. This inverse correlations between entropy and residual size was also obtained using information entropy as shown in Fig. 2.

4 Conclusions.

As long as an inverse correlation between entropy and residual size is related to an experimental inverse correlation between limit temperature and system size, this very study encourages us to perform further studies on the influence of entropy on caloric curve limit temperature. Work

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